Table 1
Screening of Leachate Treatment Technologies and Process Options
The Dalles

General Response Action	Remedial Technology	Process Option	Description	Technically Feasible and Implementable?	Effectiveness	Implementability	Cost	Treats Fe-CN Complexes?	Screening Comments
No Further Action	Current Anaerobic Biological Treatment	Biological Batch Reactor	No further action; continue leachate extraction, anaerobic biotreatment, and monitoring.	Yes	Moderate	High	Low	No	Retained for comparison with other options.
Leachate Treatment	Chemical Oxidation Treatment	Alkaline Chlorination	Chlorine is applied as $NaClO_4$ or $CaOCl_2$ at a pH of 10.5-11.5 to oxidize free and WAD CN.	Yes	High	Moderate	Moderate	No	Potential for the production of trihalomethanes which would need treatment before discharge to river.
		Ozone	Ozone is applied at a pH of 9-11 to oxidize free and WAD CN, typically within 10-15 minutes.	Yes	High	High	Moderate	No	Relatively simple setup and would treat HCN vapors as well as aqueous CN.
		UV-Enhanced Chemical Oxidation	Ultraviolet light is used to enhance radical formation to increase oxidation rates.	Yes	High	Moderate	Moderate	Yes (with H_2O_2 or O_3)	Energy intensive and O&M issues associated with UV light generation.
		Hydrogen Peroxide	Hydrogen peroxide is used at alkaline pH to oxidize free and WAD CN in the presence of a metal catalyst such as Cu, Fe, Al or Ni.	Yes	High	Moderate	Moderate	No	Best suited oxidation treatment for this waste volume and CN concentrations.
		Photocatalytic Oxidation	UV light is used to photodissociate metal-cyanide complexes. The resulting free CN is then oxidized with ozone, H_2O_2 or O_2 with a TiO_2 catalyst.	Yes	High	Moderate	Moderate	Yes	Energy intensive and O&M issues associated with UV light generation.
		INCO Air/SO2 Oxidation	A patented technology that uses Zn, Ni and Cd to precipitate FeCN followed by oxidation of free and WAD CN by SO_2 and air with a copper catalyst.	Yes	High	Moderate	Moderate	No	This technology is aimed more at tailings treatment and this application would only need the oxidation step.
		Electrochemical	Cyanide is anodically oxidized in a chloride-based solution.	Yes	High	Moderate	High	No	Typically uneconomical at cyanide concentrations below several hundred ppm.
	Separation Technologies	Activated Carbon	Granular activated carbon is used in fixed bed reactors to adsorb free CN, HCN and metal cyanides.	Yes	High	High	Low	Yes (except at high pH)	Shown to be effective in removing both free cyanide and metal-cyanide species. Requires carbon regeneration or disposal.
		Ion Exchange	Most often a strong base anion resin is used in a fixed bed reactor to remove metal-cyanide complexes after pH adjustment.	Yes	Moderate	High	Moderate	No	High cost of resin, limitations in regeneration efficiencies and concerns over HCN gas generation during regeneration.
		Activated Alumina	Activated alumina has been used to absorb ferrocyanide.	Yes	Low	High	Moderate	Yes	Not effective for removal of forms other than ferrocyanide. Ion exchange resin and activated carbon are better suited for cyanide removal.
		Iron Cyanide Precipitation	Lime is added to raise the pH, $FeSO_4$ and acid are added to the waste to precipitate Prussian Blue ($Fe_4(Fe(CN)_6)_3$ and Turnbull's Blue ($Fe_3(Fe(CN)_6)_2$ which settle out with polymer addition.	Yes	High	Moderate	Moderate	No	Sludge management and disposal costs screen this approach.

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		Air Stripping	Air is added to the waste tank to transfer HCN from the aqueous phase at reduced pH to the vapor phase. Vapors then need treatment prior to discharge.	Yes	Moderate	Moderate	Moderate	No	Typically used as a pretreatment for other treatment methods. Acid addition would be required to remove all CN.
		Steam Stripping	Steam is used in place of air to transfer HCN to the vapor phase for treament.	Yes	High	Moderate	High	No	Requires energy to generate steam and a second technology to treat vapors.
		Acid Hydrolysis	Acid is added to the waste stream to convert cyanide to gaseous HCN which is treated and discharged.	Yes	High	Moderate	Moderate	No	Requires specially designed reactors to assure that HCN vapors are properly vented and treated.
		Evaporation	A vacuum is applied to the waste stream to concentrate the CN-containing water.	No	NA	NA	NA	No	O&M issues include fouling, scaling, and avoiding HCN gas production.
		Reverse Osmosis	The waste stream is filtered and passed through a RO membrane . RO permeate then needs to be properly disposed.	Yes	Moderate	Moderate	Moderate	No	RO is sensitive to fouling and requires pre-filtration to less than one micron. Permeate requires offsite disposal.
	Thermal and High Temp. Oxidation	High Temp. Alkaline Hydrolysis	Hydrolytic cracking is used at high temperatures and pressures under alkaline conditions to oxidize CN.	Yes	High	Moderate	High	Yes	Energy intensive and better suited for high concentration wastes. No need to treat iron-CN complexes.
		High Temp. Alkaline Chlorination	Free and WAD CN and FeCN are oxidized at 170 F in 2 -3 hours.	Yes	High	Moderate	High	Yes	Energy intensive and better suited for high concentration wastes. No need to treat iron-CN complexes.
		Incineration/ Thermal	This technology is a complete combustion of CN-containing wastes in conventional incinerators.	Yes	High	Low	High	Yes	Better suited for solid wastes or high CN concentration aqueous waste streams.
		High Temp. Electrolytic Decomposition	Anodic electrolysis under alkaline conditions is used to separate the metals from the metal-CN complexes. Free CN is released and then oxidized to CO_2, N_2 and NH_3.	Yes	High	Low	High	No	No need to treat iron-CN complexes. Energy intensive.
		Polysulfide Process	A patented technology that uses an aqueous solution of ammonium polysulfide, calcium polysulfide or non-alkyl ketones of aldehydes at a temperature of 110-180 C.	Yes	High	Moderate	Moderate	Yes	No need to treat iron-CN complexes. Polysulfide is high pH and has strong odor.
		Wet Air Oxidation	Moist air is used at elevated tempuratures (175-300 C) and pressures (20-200 atm) to oxidize free CN and metal-cyanide complexes.	Yes	High	Moderate	High	Yes	Better suited for solids treatment or treatment of high concentration wastes. No need to treat iron-CN complexes.
	Aerobic Biological	Activated Sludge	Aerobic process where microbes are maintained in suspension by mixing and/or aeration. Suspended solids are separated and some returned to process (some sludge disposal also). Produces carbon dioxide and ammonia.	Yes	Moderate	Moderate	Low	No	Multiple tanks can be used to allow use of ammonia resulting in nitrogen; some loss of HCN gas is anticipated, but can be minimized; some cyanide removal via adsorption to sludge (but not in all cases).
		Aerobic Trickling Filters	Aerobic process where microbes are attached to a support media (e.g., plastic media packing) and the biofilm degrades the cyanide. Oxygen provided by air circulation. Detached biomass removed by a clarifier of discharged directly. Essentially a plug-flow hydraulic system. Produces carbon dioxide and ammonia.	Yes	High	Moderate	Moderate	No	Some cyanide removal by precipitation and adsorption. Some loss of HCN gas anticipated, but this can be minimized and managed.

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		Aerobic Rotating Contactors	An aerobic biofilm process that consists of a series of closely spaced circular plastic discs on a rotating shaft. Oxygen supplied by transfer from the air to the water film on the rotating discs. Operated in a continuous mode. Produces carbon dioxide and ammonia.	Yes	High	Moderate	Moderate	No	Full scale systems have been demonstrated, but batch reactors better suited for this application.
		Aerobic Fluidized Bed Reactors	Aerobic high-rate biological treatment where high microbical populations are attached to support particles (e.g., carbon, plastic beads, etc.) which are "fluidized" by upward flow of water and air. Produces carbon dioxide and ammonia.	Yes	High	Moderate	Moderate	No	Batch reactors are better suited to this application.
		Aerobic Batch Reactors	Includes aerobic sequencing batch reactors (SRB) and sequencing batch biofilm reactors (SBBR). Essentially a batch reactor operated in a fill-and-draw mode with potential addition of nutrients, aeration and mixing in several steps. Produces carbon dioxide and ammonia.	Yes	High	High	Low	No	May need clarification step and sludge removal/disposal; some loss of HCN gas is anticipated, but can be minimized.
	Anaerobic Biological	Upflow Anaerobic Sludge Blanket	The UASB reactor is a methanogenic system that forms a blanket of granular sludge which suspends in the tank. Wastewater flows upwards through the blanket and is processed (degraded) by the anaerobic microorganisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants. Produces methane, ammonia and formate.	Yes	High	Moderate	Moderate	No	Batch reactors are better suited to this application.
		Anaerobic Batch Reactors	Anaerobic single-step reactor with nutrient addition. Can include addition of bacterial growth support media. Produces methane, ammonia and formate.	Yes	High	High	Low	No	Current treatment tank could be enhanced for better biotreatment by adding support media for the bacteria to grow on. Also, a tank cover could be added along with HCN gas collection and treatment.
		Anaerobic Fixed Bed Reactor	Anaerobic, up-flow, fixed-bed, activated charcoal biotreatment. Addition of ethanol, phenol or methanol as a reduced carbon source. Produces methane and ammonia.	Yes	Moderate	Moderate	Moderate	No	No full scale operation; at pilot scale did not meet low cyanide discharge criteria.
	Phytoremediation	Single Plant Species	A single plant species is brought into contact with the waste stream and CN accumulates in the plants.	No	NA	NA	NA	No	Low removal efficiency and plants would need to be disposed of properly.
		Multiple Species	Multiple plant species are brought into contact with the waste stream and CN accumulates in the plants.	No	NA	NA	NA	No	Low removal efficiency and plants would need to be disposed of properly.

Retained process option